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(54) **INKJET PRINTING DEVICE AND METHOD FOR REGULATING INK CIRCULATION**

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B41J 2/045	(2006.01)
B41J 2/175	(2006.01)
B41J 29/377	(2006.01)

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CPC ***B41J 2/18*** (2013.01); ***B41J 2/0454*** (2013.01); ***B41J 2/04531*** (2013.01); ***B41J 2/04563*** (2013.01); ***B41J 2/175*** (2013.01); ***B41J 2/17556*** (2013.01); ***B41J 2/17596*** (2013.01); ***B41J 29/377*** (2013.01); *B41J 2202/08* (2013.01); *B41J 2202/12* (2013.01)

(58) **Field of Classification Search**

CPC B41J 2/175; B41J 2/17509; B41J 2/18; B41J 2/19; B41J 2/04531; B41J 2/0454; B41J 2/04563; B41J 2/17596; B41J 2202/08; B41J 2202/12

USPC 347/5, 6, 17, 85, 89, 92

See application file for complete search history.

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(57) **ABSTRACT**

An inkjet printing device includes a printer, including an inkjet head having a nozzle configured to eject ink, an ink tank configured to store the ink, a circulation path configured to circulate ink between the ink tank and the inkjet head, an ink pump configured to send the ink from the ink tank to the inkjet head in order to circulate ink and an ink temperature detector configured to detect an ink temperature, a pressure regulator configured to apply a negative pressure to the ink tank and to regulate a pressure in the ink tank and a controller configured to control the pressure regulator in accordance with the ink temperature in the printer to regulate the pressure in the ink tank and to regulate a driving rate of the ink pump.

4 Claims, 4 Drawing Sheets

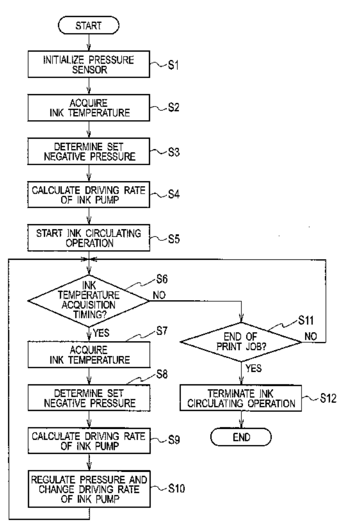


FIG. 1

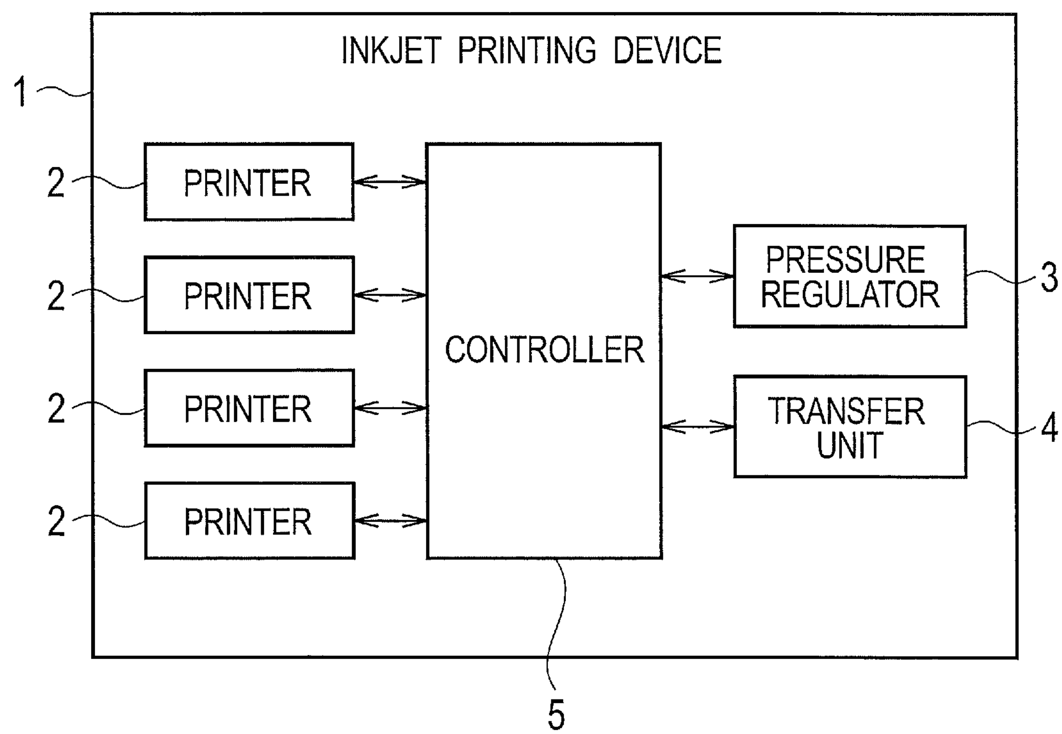
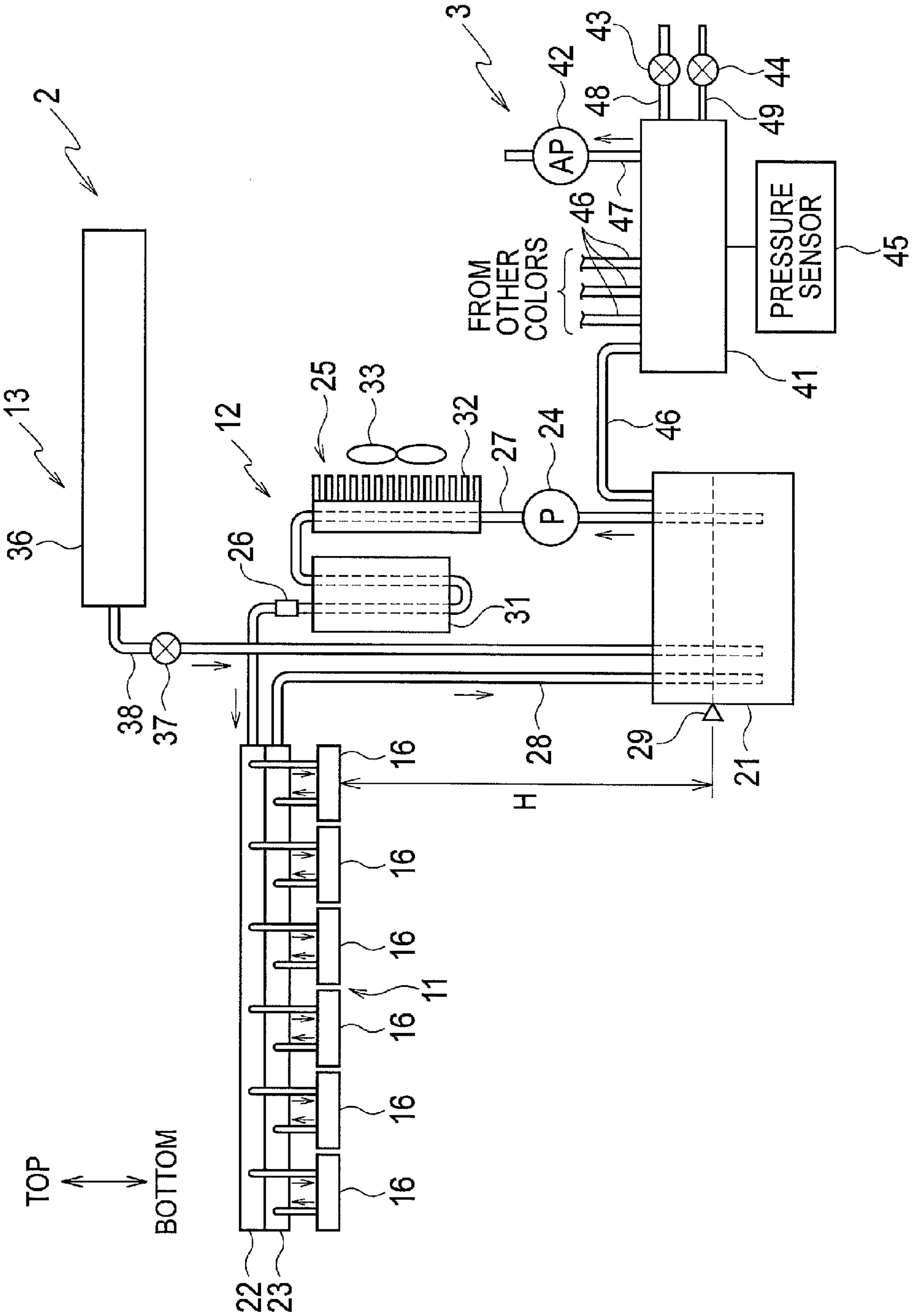

INKJET PRINTING DEVICE
1
2
PRINTER
2
PRINTER
2
PRINTER
2
PRINTER
CONTROLLER
PRESSURE REGULATOR
3
TRANSFER UNIT
4
5

FIG. 2



TOP
BOTTOM
FROM
OTHER
COLORS
PRESSURE
SENSOR
AP
P
H
2
3
11
12
13
16
21
22
23
24
25
26
27
28
29
31
32
33
36
37
38
41
42
43
44
45
46
47
48
49

FIG. 3

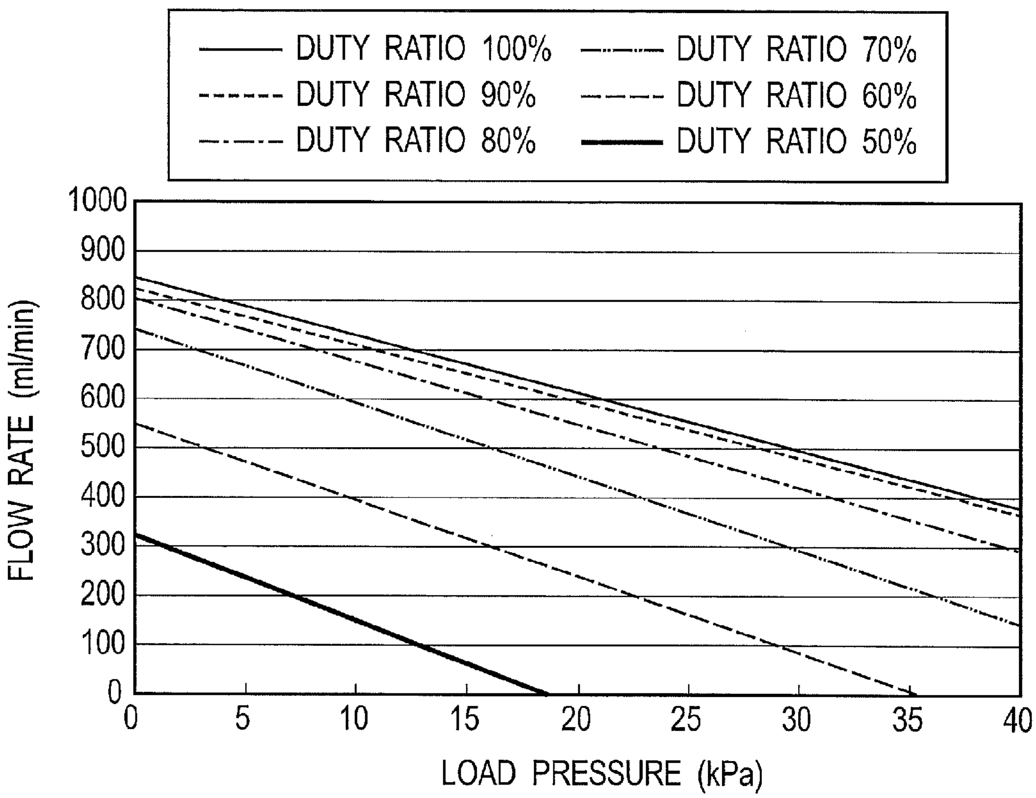
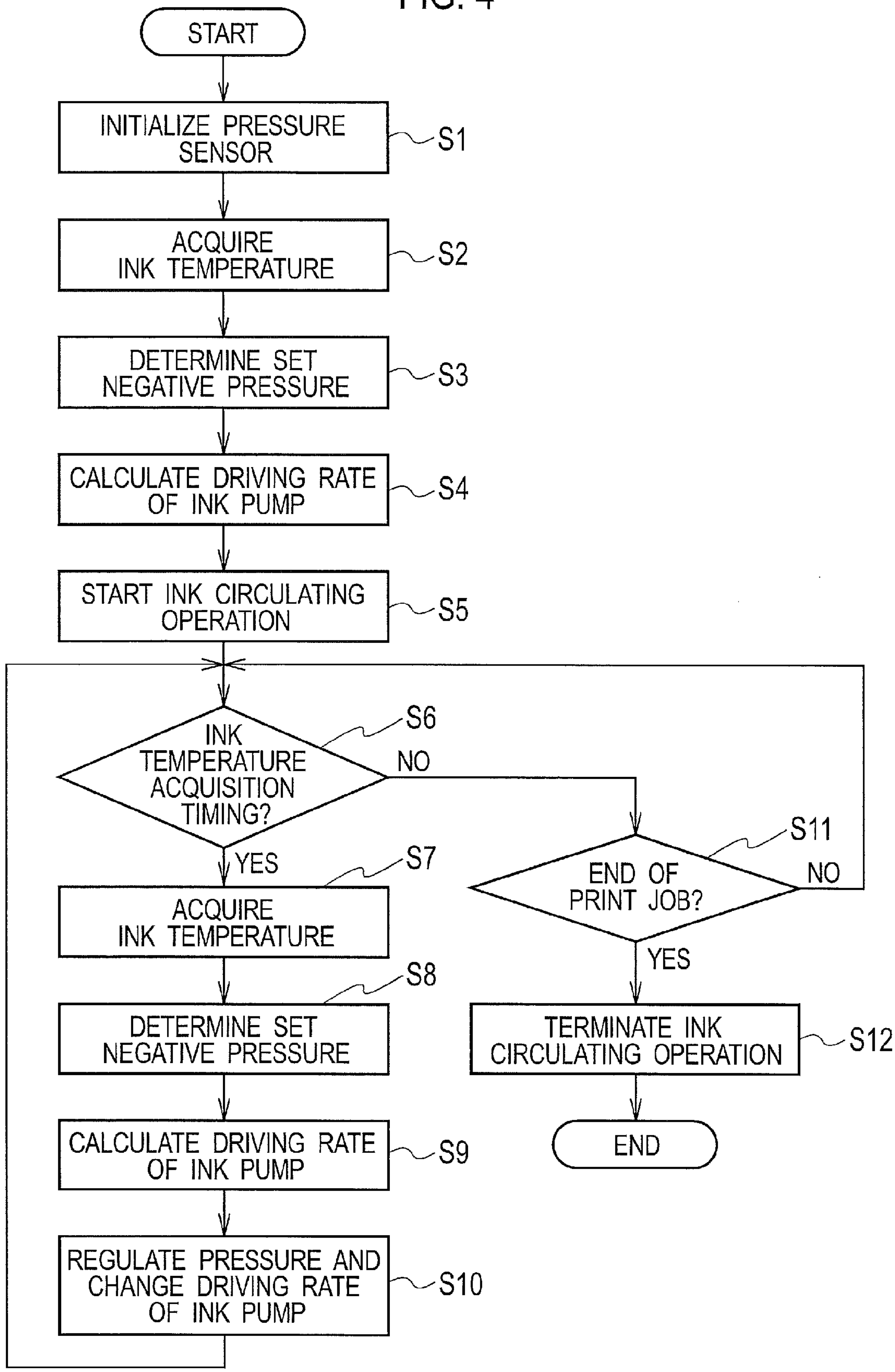

DUTY RATIO 100%
DUTY RATIO 90%
DUTY RATIO 80%
DUTY RATIO 70%
DUTY RATIO 60%
DUTY RATIO 50%
FLOW RATE (ml/min)
1000
900
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
LOAD PRESSURE (kPa)

FIG. 4


START
INITIALIZE PRESSURE SENSOR
S1
ACQUIRE INK TEMPERATURE
S2
DETERMINE SET NEGATIVE PRESSURE
S3
CALCULATE DRIVING RATE OF INK PUMP
S4
START INK CIRCULATING OPERATION
S5
INK TEMPERATURE ACQUISITION TIMING?
S6
NO
YES
ACQUIRE INK TEMPERATURE
S7
DETERMINE SET NEGATIVE PRESSURE
S8
CALCULATE DRIVING RATE OF INK PUMP
S9
REGULATE PRESSURE AND CHANGE DRIVING RATE OF INK PUMP
S10
END OF PRINT JOB?
S11
NO
YES
TERMINATE INK CIRCULATING OPERATION
S12
END

INKJET PRINTING DEVICE AND METHOD FOR REGULATING INK CIRCULATION

BACKGROUND

1. Technical Field

The present invention relates to an ink circulation type inkjet printing device.

2. Related Art

There is known an ink circulation type inkjet printing device configured to eject ink from an inkjet head to perform printing while circulating ink (see, for example, Patent Document 1).

In addition, as an ink circulation system, there is known a system configured to set a nozzle pressure of the inkjet head appropriately so as to generate a negative pressure on the downstream side of the inkjet head and to pressure-feed ink to the inkjet head by an ink pump so as to circulate the ink. In this system, the ink is circulated in order to obtain a circulation flow rate which is necessary to obtain an effect of cooling a piezoelectric element and so forth.

[Patent Document 1] Japanese Patent Application Laid-Open Publication No. 2008-162262.

SUMMARY

The inkjet head generates heat by performing an operation of ejecting ink. Thereby, the temperature of the ink is increased and the viscosity of the ink is reduced.

In the above-mentioned ink circulation system, the negative pressure on the downstream side of the inkjet head is maintained constant regardless of the temperature of the ink. Therefore, in a case where the temperature of the ink is increased and the viscosity of the ink is reduced, it is necessary to increase an amount of ink to be fed to the inkjet head in order to maintain an appropriate nozzle pressure. Hence, there is a concern that a load on the ink pump may be increased, the circulation flow rate may be increased excessively and thereby a fluctuation in nozzle pressure may be increased. In addition, when the fluctuation in nozzle pressure is increased, it is feared that the ink may be ejected unstably and a printed image quality may be deteriorated.

The present invention has been made in view of the above problem. An object of the present invention is to provide an inkjet printing device that can suppress deterioration of the printed image quality while suppressing the load on the ink pump.

In order to attain the above-mentioned object, a first feature of the inkjet printing device according to one embodiment of the present invention is to include a printer, including an inkjet head having a nozzle configured to eject ink, an ink tank configured to store the ink, a circulation path configured to circulate ink between the ink tank and the inkjet head, an ink pump configured to send the ink from the ink tank to the inkjet head in order to circulate ink and an ink temperature detector configured to detect an ink temperature; a pressure regulator configured to apply a negative pressure to the ink tank and to regulate a pressure in the ink tank; and a controller configured to control the pressure regulator in accordance with the ink temperature in the printer to regulate the pressure in the ink tank and to regulate a driving rate of the ink pump.

A second feature of the inkjet printing device according to the embodiment of the present invention is to include the printer in plurality, wherein the pressure regulator is used in common among all of the printers, and the controller determines a set negative pressure on the basis of the ink temperature in the printer and determines a necessary circulation amount of ink according to the set negative pressure, the ink temperature and a specified nozzle pressure for each of the printers, and controls the pressure regulator to regulate the pressure in the ink tank of each of the printers to the set negative pressure and to drive the ink pump at the driving rate according to the set negative pressure, the ink temperature and the necessary circulation amount for each of the printers.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be described with reference to the accompanying drawings wherein:

FIG. **1** is a block diagram illustrating a configuration of an inkjet printing device according to an embodiment.

FIG. **2** is a schematic configuration diagram illustrating a printer and a pressure regulator of the inkjet printing device illustrated in FIG. **1**.

FIG. **3** is a diagram illustrating a liquid feeding characteristic of an ink pump.

FIG. **4** is a flowchart for describing an operation of the inkjet printing device illustrated in FIG. **1**.

DETAILED DESCRIPTION

An embodiment of the present invention will be described below with reference to the drawings. The same or equivalent numerals are assigned to the same or equivalent portions and constitutional elements in the drawings. However, it is to be noted that each drawing is merely schematic and is different from reality. In addition, it goes without saying that portions which are mutually different in mutual dimensional relation and ratio are included also among the drawings.

In addition, the embodiment which will be described in the following merely illustrates a device and so forth for embodying a technical idea of the present invention and the technical idea of the present invention does not specify a material quality, a shape, a structure, an arrangement and so forth of each constitutional component to ones which will be described below. The technical idea of the present invention may be modified in a variety of ways within a range of the scope of patent claims.

FIG. **1** is a block diagram illustrating a configuration of an inkjet printing device according to one embodiment of the present invention. FIG. **2** is a schematic configuration diagram illustrating a printer and a pressure regulator of the inkjet printing device illustrated in FIG. **1**. Incidentally, a top/bottom direction will be referred to as a vertical direction in the following description and a direction from top to bottom on a plane of paper in FIG. **2** will be referred to as the top/bottom direction.

As illustrated in FIG. **1**, an inkjet printing device **1** according the present embodiment includes four printers **2**, a pressure regulator **3**, a transfer unit **4** and a controller **5**.

The printer **2** ejects ink to a sheet which is transferred by the transfer unit **4** and prints an image on the sheet while circulating the ink. The four printers **2** eject ink of mutually different colors (for example, black (K), cyan (C), magenta (M) and yellow (Y)). The four printers **2** have the same configuration excepting that the colors of ink to be ejected are mutually different.

As illustrated in FIG. **2**, the printer **2** includes an inkjet head **11**, an ink circulation unit **12** and an ink replenishment unit **13**.

The inkjet head **11** ejects the ink supplied from the ink circulation unit **12**. The inkjet head **11** includes a plurality of head modules **16**.

Each of the head modules **16** includes an ink chamber (not illustrated) which stores ink therein and a plurality of nozzles (not illustrated) through which ink is ejected. A piezoelectric element (not illustrated) is arranged in the ink chamber. The ink is ejected through the nozzle with drive of the piezoelectric element. The plurality of head modules **16** is arranged such that the heights of nozzle surfaces (lower surfaces) where the nozzles open are made the same as one another among all of the head modules **16**.

The ink circulation unit **12** supplies ink to the inkjet head **11** while circulating the ink. The ink circulation unit **12** includes an ink tank **21**, an ink distributor **22**, an ink collector **23**, an ink pump **24**, an ink temperature regulator **25**, an ink temperature sensor **26** (an ink temperature detector), and ink conduits **27**, **28**.

The ink tank **21** stores ink to be supplied to the inkjet head **11**. Ink is replenished into the ink tank **21** from the ink replenishment unit **13**. In addition, ink which has not been consumed in the inkjet head **11** is fed back to the ink tank **21** through the ink collector **23** and the ink conduit **28**. An air layer is formed on a liquid surface of the ink in the ink tank **21**. The ink tank **21** is arranged at a position lower than (below) the inkjet head **11**.

The ink tank **21** includes a liquid surface sensor **29**. The liquid surface sensor **29** is configured to detect whether or not the liquid surface height of ink in the ink tank **21** reaches a reference height. When the liquid surface height of the ink in the ink tank **21** is not less than the reference height, the liquid surface sensor **29** outputs a signal indicating “ON”. While, when the liquid surface height of the ink is less than the reference height, the liquid surface sensor **29** outputs a signal indicating “OFF”.

The ink distributor **22** distributes the ink supplied from the ink tank **21** to each head module **16** of the inkjet head **11** through the ink conduit **27**.

The ink collector **23** collects the ink which has not been consumed in the inkjet head **11** from each head module **16**. The ink which has been collected by the ink collector **23** flows into the ink tank **21** through the ink conduit **28**.

The ink pump **24** feeds ink from the ink tank **21** to the inkjet head **11** in order to circulate the ink. The ink pump **24** is provided in the middle of the ink conduit **27**.

The ink temperature regulator **25** regulates the temperature of the ink in the ink circulation unit **12**. The ink temperature regulator **25** is provided in the middle of the ink conduit **27**. The ink temperature regulator **25** includes a heater **31**, a heat sink **32**, and a cooling fan **33**.

The heater **31** heats the ink in the ink conduit **27**. The heat sink **32** cools the ink in the ink conduit **27** by heat radiation. The cooling fan **33** sends cooling air to the heat sink **32**.

The ink temperature sensor **26** detects an ink temperature T_i in the ink circulation unit **12**. The ink temperature sensor **26** is provided in the middle of the ink conduit **27**.

The ink conduit **27** connects the ink tank **21** with the ink distributor **22**. Ink flows from the ink tank **21** toward the ink distributor **22** through the ink conduit **27**. The ink conduit **28** connects the ink collector **23** with the ink tank **21**. Ink flows from the ink collector **23** toward the ink tank **21** through the ink conduit **28**. The ink conduits **27** and **28**, the ink distributor **22** and the ink collector **23** form a circulation path through which ink is circulated between the ink tank **21** and the inkjet head **11**.

The ink replenishment unit **13** replenishes ink into the ink circulation unit **12**. The ink replenishment unit **13** includes an ink cartridge **36**, an ink replenishment valve **37**, and an ink conduit **38**.

The ink cartridge **36** contains ink to be used for printing by the inkjet head **11**. The ink in the ink cartridge **36** is supplied into the ink tank **21** of the ink circulation unit **12** through the ink conduit **38**.

The ink replenishment valve **37** opens and closes an ink flow path in the ink conduit **38**. When the ink is to be replenished into the ink tank **21**, the ink replenishment valve **37** is opened.

The ink conduit **38** connects the ink cartridge **36** with the ink tank **21**. Ink flows from the ink cartridge **36** toward the ink tank **21** through the ink conduit **38**.

The pressure regulator **3** applies a negative pressure to the ink tank **21** and regulates a pressure in the ink tank **21**. The pressure regulator **3** is configured to be used in common among all of the printers **2**. The pressure regulator **3** includes a common air chamber **41**, an air pump **42**, an atmospheric air open valve **43**, a pressure regulating valve **44**, a pressure sensor **45**, four air conduits **46**, and air conduits **47**, **48**, **49**.

The common air chamber **41** is a chamber configured to equalize the pressures in the ink tanks **21** of the respective printers **2**. The common air chamber **41** communicates with air layers in the ink tanks **21** of the four printers **2** through the four air conduits **46**. Thereby the ink tanks **21** of the respective printers **2** are brought into communication with one another through the common air chamber **41** and the air conduits **46**.

The air pump **42** sucks air from the common air chamber **41** through the air conduit **47** and applies the negative pressure to the common air chamber **41** and the ink tank **21** of each of the printers **2**. The air pump **42** is provided in the middle of the air conduit **47**.

The atmospheric air open valve **43** opens and closes an air flow path in the air conduit **48** in order to switch a state of each of the common air chamber **41** and the ink tank **21** of each printer **2** between a sealed state (a state being shut off from the atmosphere) and an atmospheric air open state (a state leading to the atmosphere). The atmospheric air open valve **43** is provided in the middle of the air conduit **48**.

The pressure regulating valve **44** opens and closes an air flow path in the air conduit **49** in order to regulate the pressures in the common air chamber **41** and the ink tank **21** of each of the printers **2**. The pressure regulating valve **44** is provided in the middle of the air conduit **49**.

The pressure sensor **45** detects the pressure in the common air chamber **41**. The pressure in the common air chamber **41** is equal to the pressure in the ink tank **21** of each of the printers **2**. This is because the common air chamber **41** communicates with the air layer in the ink tank **21** of each of the printers **2** through the air conduit **46**.

The four air conduits **46** each connects the common air chamber **41** with the ink tank **21** of each of the four printers **2**. The air conduit **46** is connected to the common air chamber **41** at one end and is connected to the air layer in the ink tank **21** at the other end.

The air conduit **48** forms an air flow path for opening the common air chamber **41** and the ink tanks **21** to the atmosphere. The air conduit **48** is connected to the common air chamber **41** at one end and leads to the atmosphere at the other end.

The air conduit **49** forms an air flow path for regulating pressures in the common air chamber **41** and the ink tanks **21**. The air conduit **49** is configured by a pipe which is larger in flow path resistance than the air conduit **48**. Specifically, the air conduit **49** is configured by the pipe which is thinner than the air conduit **48**. The air conduit **49** is connected to the common air chamber **41** at one end and leads to the atmosphere at the other end.

The transfer unit **4** takes a sheet out of a paper feed tray (not illustrated) and transfers the sheet along a transfer path (not illustrated). The transfer unit **4** includes a roller (not illustrated) for transferring the sheet, a motor (not illustrated) for driving the roller and so forth.

The controller **5** controls an operation of each unit of the inkjet printing device **1**. The controller **5** is configured by including a CPU, a RAM, a ROM, a hard disc and so forth.

The controller **5** regulates the pressure in each of the ink tanks **21** by the pressure regulator **3** in accordance with the ink temperature T_i in each printer **2** and regulates a driving rate (a duty ratio) of the ink pump **24**.

Specifically, the controller **5** determines a set negative pressure P_f in the ink tank **21** on the basis of the ink temperature T_i in each of the printers **2** and determines a necessary circulation flow rate Q_n of ink according to the set negative pressure P_f, the ink temperature T_i, and a specified nozzle pressure P_n for every printer **2**. In addition, the controller **5** determines the driving rate of the ink pump **24** according to the set negative pressure P_f, the ink temperature T_i, and the necessary circulation flow rate Q_n for every printer **2**. Then, the controller **5** regulates the pressure in each of the ink tanks **21** to the set negative pressure P_f by the pressure regulator **3** and drives the ink pump **24** at the driving rate which has been determined for every printer **2**.

The controller **5** stores theoretical values of flow path resistances (flow path resistance/viscosity) per viscosity of ink for each of an upstream side flow path and a downstream side flow path in the ink circulation unit **12**.

The upstream side flow path is an ink flow path configured by the ink conduit **27**, the ink distributor **22**, and a flow path between an input port and the nozzle of each head module **16** of the inkjet head **11**. The downstream side flow path is an ink flow path configured by a flow path between the nozzle and an output port of each head module **16** of the inkjet head **11**, the ink collector **23**, and the ink conduit **28**.

The flow path resistance is proportional to a viscosity μ of ink. The flow path resistance per viscosity is a proportional coefficient of the flow path resistance. The flow path resistance per viscosity is determined depending on the shape of the flow path concerned. The flow path resistance per viscosity is used for calculating a flow path resistance R_u of the upstream side flow path and a flow path resistance R_d of the downstream side flow path from the viscosity μ according to the ink temperature T_i. The flow path resistance R_d of the downstream side flow path is used for calculating a later described standard negative pressure P_t when determining the set negative pressure P_f. The flow path resistance R_u of the upstream side flow path is used for calculating a load pressure P which is necessary to determine the driving rate of the ink pump **24**.

The controller **5** stores a calculation formula used for obtaining the viscosity μ of ink from the ink temperature T_i for ink of each color corresponding to each of the printers **2**. The viscosity μ of ink is used for calculating the flow path resistance R_u of the upstream side flow path and the flow path resistance R_d of the downstream side flow path.

The controller **5** stores a calculation formula used for obtaining a density ρ of ink from the ink temperature T_i for ink of each color. The density ρ of ink is used for calculating a later described standard negative pressure P_t when determining the set negative pressure P_f. In addition, the density ρ of ink is used for calculating a later described necessary circulation flow rate Q_n when determining the driving rate of the ink pump **24**.

The controller **5** stores a calculation formula used for obtaining the driving rate (the duty ratio) from the load pressure P and a flow rate Q of the ink pump **24**. Here, the ink pump **24** has a liquid feeding characteristic (PQ characteristic) according to the driving rate, for example, as illustrated in FIG. **3**. A calculation formula for the driving rate of the ink pump **24** is prepared so as to allow calculation of the driving rate from the load pressure P and the flow rate Q on the basis of the PQ characteristic as illustrated in FIG. **3**. There are cases where there exists a plurality of the calculation formulae for the driving rate of the ink pump **24** in accordance with a range of the load pressure P.

Next, an operation of the inkjet printing device **1** will be described.

FIG. **4** is a flowchart for describing the operation of the inkjet printing device **1**. Processing in the flowchart in FIG. **4** is started by inputting a print job into the inkjet printing device **1**.

In step **S1** in FIG. **4**, the controller **5** performs initialization of the pressure sensor **45**.

Then, in step **S2**, the controller **5** acquires the ink temperature T_i from the ink temperature sensor **26** of each printer **2**.

Then, in step **S3**, the controller **5** determines the set negative pressure P_f of the ink tank **21**.

Specifically, first, the controller **5** calculates the standard negative pressure P_t of the ink tank **21** at the current ink temperature T_i in each of the printers **2**. The standard negative pressure P_t is calculated by the following Mathematical formula 1.

$$P_t = -Q_{min} \cdot R_d + P_n + H \cdot \rho \cdot g \qquad \text{[Mathematical formula 1]}$$

The standard negative pressure P_t [unit: Pa] is a pressure of the ink tank **21** at which the nozzle pressure reaches the specified nozzle pressure P_n [unit: Pa] at a circulation flow rate of a minimum required flow rate Q_{min} [unit: m^3/s].

The minimum required flow rate Q_{min} is a minimum circulation flow rate which is required to cool the piezoelectric element of the head module **16** of the inkjet head **11** and to wash away air bubbles and foreign materials (dust, viscosity-increased ink and so forth) which are present in the vicinity of the nozzle. The minimum required flow rate Q_{min} has a fixed value which has been set in advance.

The specified nozzle pressure P_n is set in advance as a nozzle pressure which is appropriate for ink ejection.

The flow path resistance R_d [unit: $Pa \cdot s/m^3$] of the downstream side flow path is calculated from a theoretical value of a flow path resistance (flow path resistance/viscosity) per viscosity of the downstream side flow path and the viscosity μ [unit: Pa·s] of ink. The viscosity μ is calculated from the ink temperature T_i.

H [unit: m] is a difference in height (water head difference) between a nozzle surface (a lower surface) of the head module **16** of the inkjet head **11** and a liquid surface (a reference height) of the ink tank **21** as illustrated in FIG. **2**.

The density ρ [unit: kg/m^3] of ink is calculated from the ink temperature T_i. g [unit: m/s^2] is a gravitational acceleration.

In Mathematical formula 1, the first term [$Q_{min} \cdot R_d$] expresses the magnitude of a pressure loss generated on the downstream side flow path relative to the minimum required flow rate Q_{min} and the second term [H·ρ·g] expresses a water head pressure.

The controller **5** calculates the standard negative pressure P_t according to the ink temperature T_i in each printer **2** by using Mathematical formula 1 and then determines a minimum value (which is maximum in absolute value) in the values of the standard negative pressure P_t of each printer **2** as the set negative pressure P_f.

Then, in step S**4**, the controller **5** calculates the driving rate of the ink pump **24** of each printer **2**.

Specifically, first, the controller **5** calculates the necessary circulation flow rate Q_n [unit: m^3/s] of ink according to the set negative pressure P_f, the ink temperature T_i and the specified nozzle pressure P_n in regard to each printer **2**. The necessary circulation flow rate Q_n is calculated by the following Mathematical formula 2.

$$Q_n = \frac{-P_f + P_n + H \cdot \rho \cdot g}{R_d} \quad \text{[Mathematical formula 2]}$$

The necessary circulation flow rate Q_n is a circulation flow rate which is required to set the nozzle pressure to the specified nozzle pressure P_n when the pressure of the ink tank **21** has been set to the set negative pressure P_f at the current ink temperature T_i. Incidentally, in the printer **2** in which the standard negative pressure P_t has been adopted as the set negative pressure P_f, the minimum required flow rate Q_{min} is set as the necessary circulation flow rate Q_n.

Then, the controller **5** calculates the load pressure P [unit: Pa] of the ink pump **24** according to the set negative pressure P_f, the ink temperature T_i and the necessary circulation flow rate Q_n in regard to each printer **2**. The load pressure P is calculated by the following Mathematical formula 3.

$$P = -P_f + Q_n \cdot R_u \quad \text{[Mathematical formula 3]}$$

Here, the flow path resistance R_u [unit: $Pa \cdot s/m^3$] of the upstream side flow path is calculated from a theoretical value of the flow path resistance (flow path resistance/viscosity) per viscosity of the upstream side flow path and the viscosity μ according to the ink temperature T_i. In Mathematical formula 3, the second term [$Q_n \cdot R_u$] indicates the magnitude of the pressure loss generated on the upstream side flow path relative to the necessary circulation flow rate Q_n.

Then, the controller **5** calculates the driving rate of the ink pump **24** according to the load pressure P and the necessary circulation flow rate Q_n in each printer **2** by using the aforementioned calculation formula of the driving rate according to the PQ characteristic.

Then, in step S**5**, the controller **5** starts an ink circulating operation. Specifically, first, the controller **5** closes the atmospheric air open valve **43**. Incidentally, in a standby mode that the inkjet printing device **1** does not perform the ink circulating operation, the atmospheric air open valve **43** is opened and the ink tank **21** is opened to the atmosphere. The pressure regulating valve **44** is kept closed since the inkjet printing device **1** is in the standby mode.

Then, the controller **5** starts driving of the air pump **42**. The common air chamber **41** and the ink tank **21** are decompressed by driving of the air pump **42**. The controller **5** controls to stop the air pump **42** when a detection value of the pressure sensor **45** reaches the set negative pressure P_f.

In addition, the controller **5** starts driving of the ink pump **24** of each printer **2**, simultaneously with start of driving of the air pump **42**. Here, the controller **5** drives the ink pump **24** of each printer **2** at the driving rate which has been calculated in step S**4**.

The negative pressure is applied to the ink tank **21** by the air pump **42** and the ink pump **24** is driven, and thereby the ink is circulated along the circulation path of the ink circulation unit **12**.

While the ink circulating operation is being performed, the controller **5** executes a print job. Specifically, the controller **5** allows the inkjet head **11** to eject ink onto a sheet which is transferred by the transfer unit **4** on the basis of the print job. Thereby, an image is printed on the sheet.

When the amount of ink in the ink circulation unit **12** is reduced by being used for printing, the controller **5** controls the ink replenishment unit **13** so as to replenish ink. Specifically, when the liquid surface of the ink tank **21** is lowered due to a reduction in ink in the ink circulation unit **12** and the liquid surface sensor **29** is turned off, the controller **5** opens the ink replenishment valve **37**. Thereby, the ink in the ink cartridge **36** is supplied into the ink tank **21**. When the ink is supplied, the liquid surface of the ink tank **21** goes up and the liquid surface sensor **29** is turned on, the controller **5** closes the ink replenishment valve **37**.

In addition, when the inkjet head **11** performs an ejecting operation while the ink circulating operation is being performed, heat is generated from the inkjet head **11** and the temperature of the ink is increased by being influenced by heat generation. Against temperature rising, the controller **5** controls the ink temperature regulator **25** to regulate the ink temperature so that a temperature detected by the ink temperature sensor **26** does not deviate from a print-allowable temperature range of the inkjet head **11**.

A fluctuation in ink temperature T_i arises due to driving of the inkjet head **11** and temperature regulation by the ink temperature regulator **25** while the ink circulating operation is being performed as mentioned above. Against the fluctuation in temperature, the controller **5** regulates the pressure in the ink tank **21** and the driving rate of the ink pump **24** in accordance with the fluctuation in ink temperature T_i still while the ink circulating operation is being performed.

Specifically, after the ink circulating operation has been started, in step S**6**, the controller **5** determines whether or not an ink temperature acquisition timing has come. The ink temperature acquisition timing is set at a predetermined time interval after the ink circulating operation has been started.

When it is determined that the ink temperature acquisition timing has come (step S**6**: YES), the controller **5** proceeds to step S**7**. Processing in steps S**7**, S**8** and S**9** is the same as the processing in steps S**2**, S**3** and S**4**.

Following step S**9**, in step S**10**, the controller **5** controls the pressure regulator **3** to regulate the pressure in the ink tank **21** to the set negative pressure P_f which has been determined in step S**8**. At the same time, the controller **5** changes the driving rate of the ink pump **24** to the driving rate which has been determined in step S**9**.

Here, regulation of the pressure in the ink tank **21** is performed by the air pump **42** or the pressure regulating valve **44**. Specifically, when the pressure of the ink tank **21** is to be reduced, the controller **5** drives the air pump **42**. Thereby, air is sucked from the common air chamber **41** and the pressure in the ink tank **21** is reduced together with pressure reduction in the common air chamber **41**. While, when the pressure in the ink tank **21** is to be increased, the controller **5** opens the pressure regulating valve **44**. Thereby, air flows into the common air chamber **41** and the pressure in the ink tank **21** is increased together with pressure increase in the common air chamber **41**.

After step S**10**, the controller **5** returns to step S**6**.

In step S**6**, when it is determined that the ink temperature acquisition timing has not yet come (step S**6**: NO), in step

S11, the controller **5** determines whether or not the print job has been terminated. When it is determined that the print job has not yet been terminated (step S**11**: NO), the controller **5** returns to step S**6**.

When it is determined that the print job has been terminated (step S**11**: YES), in step S**12**, the controller **5** terminates the ink circulating operation. Specifically, the controller **5** opens the atmospheric air open valve **43** and stops the ink pump **24**. Thereby, the inkjet printing device **1** stops the operation and enters a standby state.

As described above, in the inkjet printing device **1**, the controller **5** regulates the pressure in the ink tank **21** and the driving rate of the ink pump **24** in accordance with the ink temperature T_i of each printer **2**. Specifically, the controller **5** determines the set negative pressure P_f in the ink tank **21** on the basis of the ink temperature T_i of each printer **2** and determines the necessary circulation flow rate Q_n of ink according to the set negative pressure P_f, the ink temperature T_i and the specified nozzle pressure P_n for every printer **2**. In addition, the controller **5** determines the driving rate of the ink pump **24** according to the set negative pressure P_f, the ink temperature T_i and the necessary circulation flow rate Q_n for every printer **2**. Then, the controller **5** regulates the pressure in each ink tank **21** to the set negative pressure P_f by the pressure regulator **3** and drives the ink pump **24** at the driving rate which has been determined for every printer **2**.

Thereby, it becomes possible for the inkjet printing device **1** to suppress the fluctuation in circulation flow rate of ink and the fluctuation in nozzle pressure according to the fluctuation in ink temperature T_i in each printer **2**. Consequently, it is possible to suppress deterioration of printed image quality while suppressing the load on the ink pump **24** of each printer **2**. In addition, since use of the ink pump **24** of high performance is not necessary, it is possible to avoid an increase in size of the device.

Although in the above-mentioned embodiment, description has been made in regard to the inkjet printing device **1** including the four printers **2**, the number of the printers **2** is not limited to four. The present invention is also applicable to the case of using one printer **2**.

In case of a configuration of one printer **2**, the standard negative pressure P_t of the ink tank **21** at the ink temperature T_i of the printer **2** concerned may be set as the set negative pressure P_f. In addition, the driving rate of the ink pump **24** may be calculated by setting the minimum required flow rate Q_{min} as the necessary circulation flow rate Q_n and the ink pump **24** may be driven at the calculated driving rate.

Even in case of the configuration of one printer **2**, it is possible to suppress the fluctuation in circulation flow rate of ink and the fluctuation in nozzle pressure according to the fluctuation in ink temperature T_i by regulating the pressure in the ink tank **21** and the driving rate of the ink pump **24** in accordance with the ink temperature T_i of the printer **2** concerned in this way. Thereby, it is possible to suppress deterioration of printed image quality while suppressing the load on the ink pump **24**.

As the air pump **42**, a pump of the type which is inversely rotatable may be also used. In this case, also pressure application to the ink tank **21** becomes possible by the air pump **42**. Therefore, it is possible to eliminate the pressure regulating valve **44** and the air conduit **49**.

While embodiments of the present invention have been described hereinabove, these embodiments are merely illustration described for the purpose of facilitating the understanding of the present invention, and the present invention is not limited to the embodiments. The technical scope of the present invention is not limited to the specific technical matters disclosed in the embodiments but includes various modifications, changes, alternative techniques, and the like which can readily be conceived therefrom.

The entire content of Japanese Patent Application No. 2014-168226 (filed on Aug. 21, 2014) is incorporated herein by reference.

INDUSTRIAL APPLICABILITY

In the inkjet printing device according to the embodiment of the present invention, it is possible to suppress the fluctuation in circulation flow rate of ink and the fluctuation in nozzle pressure according to the fluctuation in ink temperature by regulating the pressure in the ink tank and the driving rate of the ink pump in accordance with the ink temperature of the printer concerned. Thereby, it is possible to suppress deterioration of printed image quality while suppressing the load on the ink pump.

What is claimed is:

1. An inkjet printing device, comprising:

a printer, including
- an inkjet head having a nozzle configured to eject ink,
- an ink tank configured to store the ink,
- a circulation path configured to circulate the ink between the ink tank and the inkjet head,
- an ink pump configured to send the ink from the ink tank to the inkjet head in order to circulate the ink, and
- an ink temperature sensor configured to detect an ink temperature;

a pressure regulator configured to apply a negative pressure to the ink tank and to regulate a pressure in the ink tank; and

a controller configured to set a set pressure for the ink tank on the basis of the ink temperature in the printer, to control the pressure regulator to regulate the pressure in the ink tank, and to regulate a driving rate of the ink pump in accordance with the set pressure for the ink tank.

2. The inkjet printing device according to claim **1**, wherein

the pressure regulator is used in common for the printer and another printer, and

the controller determines a circulation amount of ink according to the set pressure, the ink temperature and a specified nozzle pressure for each of the printer and the another printer, and controls the pressure regulator to regulate the pressure in the ink tank of each of the-printer and the another printer to the set pressure and to drive the ink pump at the driving rate according to the set pressure, the ink temperature and the circulation amount for each of the printer and the another printer.

3. The inkjet printing device according to claim **1**, wherein the controller calculates a flow rate of ink according to the set pressure.

4. The inkjet printing device according to claim **1**, wherein the controller controls the pressure regulator to maintain the set pressure.

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